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Kobus, David A., Palmer, Erica D., Kobus, Jason, Ostertag, Jared

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14. ABSTRACT

This technical paper reports upon the measurement of behavioral observations and physiological monitoring of heart rates from individual infantrymen to determine whether a sense of presence occurred during virtual scenarios in the Operational Demonstrations of Spiral 1 of the Future Immersive Training Environment Joint Capability Technology Demonstration (FITE JCTD). During this study Army and Marine Corps infantry squads participated in multiple virtual combat scenarios. Each participant wore an Expedition Dismounted Infantryman (ExDI) suit which allowed him to control an avatar within a Virtual Battlespace 2 (VBS2) scenario. Behavioral observations were used to identify participant actions or behaviors that demonstrated signs of presence. A physiological measure (heart rate / HR variability) was also collected from four squads (2 USMC, 2 USA) during each of four scenarios. This measure was used to determine whether the participant's heart rate (HR) during the scenario differed from baseline HR. Individual HR data were also correlated to scenario event time markers (e.g., sniper shot) to denote individual levels of presence during the event. The behavioral observation and physiological measures described in this report appear to be effective for determining whether participants experience a sense of presence, being *in* the environment opposed to just *watching* it, during virtual scenarios.

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Presence; immersion; virtual reality; immersive training; physiological monitoring; heart rate

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Physiological and Behavioral Assessment of Presence: FITE JCTD Spiral 1 Operational Demonstration

PSE Report: 10-10

David A. Kobus

Erica D. Palmer

Jason Kobus

Jared Ostertag

Pacific Science & Engineering Group, Inc.

Executive Summary

This technical paper reports upon the measurement of behavioral observations and physiological monitoring of heart rates from individual infantrymen to determine whether a sense of presence occurred during virtual scenarios in the Operational Demonstrations of Spiral 1 of the Future Immersive Training Environment Joint Capability Technology Demonstration (FITE JCTD). The goals of this work were to 1) identify whether the FITE immersive environment could provide a level of stress that could be measured behaviorally and physiologically and 2) Determine whether behavioral data and physiological measures could be used as indicators of presence, which is a sense of being ***in*** the environment rather than a sense of ***watching it***.

During this study Army and Marine Corps infantry squads participated in multiple virtual combat scenarios. Each participant wore an Expedition Dismounted Infantryman (ExDI) suit which allowed him to control an avatar within a Virtual Battlespace 2 (VBS2) scenario. Behavioral observations were used to identify participant actions or behaviors that demonstrated signs of presence. A physiological measure (heart rate / HR variability) was also collected from four squads (2 USMC, 2 USA) during each of four scenarios. This measure was used to determine whether the participant's heart rate (HR) during the scenario differed from baseline HR. Individual HR data were also correlated to scenario event time markers (e.g., sniper shot) to denote individual levels of presence during the event.

Observations by PSE researchers indicated that participants did feel a sensation of presence during the virtual scenarios, exhibiting real-world actions and behaviors while in the virtual world of the VBS2 scenarios. Examples of these behaviors and actions indicating presence are listed in the following table.

Example Observed Behaviors and Actions
Using hand gestures while talking
Pointing in the real world the direction someone is facing
Indicating to a squad member that they need to use their radio to talk because they are not close
Ducking when an unknown, possibly hostile aircraft flew over
Feeling nervous while standing near an IED in the virtual world

In order to use HR data to determine whether a participant experiences a sense of presence during the scenarios, HR changes were examined relative to key scenario events. The results show that specific events did produce a sensation of presence for participants. Heart rate zones were also classified by level of Cooper's Color Code (CCC), based on previously postulated ranges of HR (cf., Grossman & Christensen, 2004) to measure the level of engagement of the participant. The results showed that most participants spent a majority of their time in condition yellow, which is the desired condition when on patrol.

The behavioral observation and physiological measures described here appear to be effective for determining whether participants experience a sense of presence during virtual scenarios. While there were potentially confounding variables such as caffeine and nicotine use that could not be controlled for during the Spiral 1 Operational Demonstrations, the data indicate that a sense of presence was successfully induced by the FITE virtual environment. Future research will help determine whether the scenarios and the key scenario events consistently produce this sensation of presence in participants.

Physiological and Behavioral Assessment of Immersion: FITE JCTD Spiral 1 Operational Demonstration

The Future Immersive Training Environment (FITE) Joint Capability Technology Demonstration (JCTD) Management and Transition Plan (MTP) dated 26 Feb 2010 stated that one of the desired capabilities to be demonstrated during Spiral 1 were to:

> *The integrated, interoperable, immersive training environment will replicate elements of the visual, audio, tactile, olfactory effects, and conditions of the battlefield across the spectrum of operations situational awareness, cognitive skills and higher order decision making. Team members will be able to exercise complex kinetic and non-kinetic and higher order decision making under stressful conditions. Team members will exercise close combat tasks in a realistic fully immersive training environment that reinforce ethical decision making against an asymmetric enemy employing Improvised Explosive Devices (IEDs), criminal networks and insurgency tactics. The environment will provide culturally realistic, reactive, dynamic, synthetic entities that allow realistic interaction within the Joint Operating Environment (JOE) (i.e., team members, higher headquarters, and adjacent units, supporting arms, civilians, and opposing forces (OPFOR)). The training environment will facilitate repeatable and rapidly reconfigurable scenarios and training systems or ranges. The environment will provide real-time, physically accurate representation of ballistic effects (Indirect fire, IEDs, etc.). (ONR 2010, Pg. 2)*

This was elaborated further in Critical Operational Issue (COI) number 3 by posing the question:

> *Will the JCTD capabilities generate a realistic and interactive training environment which assists the unit in meeting established training standards? (ONR 2010, Pg.20)*

While it is currently not possible, or feasible to replicate a realistic battlefield environment, it is still possible to create a system that replicates many of the characteristics of combat. The general hypothesis is that the more realistic the training environment, the greater the immersion, providing more of a sense of presence to the trainee. One goal of Spiral 1 of the FITE JCTD was to develop a training environment that could present a realistic combat environment to trainees to produce the sensation of presence. The methods identified and used in this report were specifically targeted at evaluating whether trainees demonstrated a sense of presence within the training environment.

The goal of the FITE JCTD is to create an immersive environment, but how should immersion be operationally defined? Ijesselstein and Riva (2003) define immersion, in technical terms. It is

the technology that sets the environment by producing cues that make an individual sense as if they were part of the environment. The actual sensation experienced by the trainee working in the environment indicates their level of presence. In other words, immersion is produced by technology to produce the sensation of presence.

Witmer and Singer (1998) define presence as "the subjective experience of being in one place or environment, even when one is physically situated in another" (pg. 225) and offer the following factors as ones that contribute to the sense of presence:

> Control Factors - Degree of control; Immediacy of control; Anticipation of control; Mode of control; Physical environment modifiability
>
> Sensory Factors - Sensory modality; richness of environment; Multimodal presentation; Consistency of multimodal information; Degree of movement perception; Active search
>
> Distraction Factors - Isolation; Selective attention; Interface awareness
>
> Realism Factors - Scene realism; Information consistent with objective world; Meaningfulness of experience; Separation anxiety/disorientation

One way to measure the factors of presence is to collect subjective data from presence questionnaires (or surveys). Presence questionnaires ask questions of the participant about their experience using the virtual system, post-immersion. These questionnaires may provide some good information, but a major disadvantage of using post-immersion questionnaires is that they are post-immersion, meaning that the questionnaires do not measure the time-varying qualities of presence and they may be more influenced by events that occurred near, or at the end of the immersion, which is closer to the administration of the questionnaire (Insko, 2003).

Further, Slater (2003) argues that the use of presence questionnaires alone is an "unsafe" methodology since it is difficult to rule out the possibility that the phenomenon being measured is not influenced by simply asking questions about it. The questionnaires themselves may be influencing the responses of the participant whether they sensed presence or not. Therefore, other measures need to be identified to compliment the presence questionnaires.

Insko (2003) describes two additional categories of measures that can be used in concert with subjective measures. The first is behavioral observations; the premise is that the more a participant senses a presence in the virtual environment, the more their responses to stimuli in the virtual environment, will match behaviors they would exhibit in an identical real environment. The second set of measures is physiological indicators. Insko suggests three common and minimally intrusive ways to measure presence physiologically (heart rate, skin conductance, and skin temperature).

Mandryk (2006) found that while subjective data (surveys and questionnaires) do yield valuable quantitative and qualitative results, they do not provide sufficient information when used alone.

Mandryk's team recorded users' physiological, verbal and facial reactions to game technology to evaluate their experience. They found a significant correlation between subjective ratings and physiological responses. They suggest that by using multiple techniques to evaluate participants' experience, presence can be measured in a more objective manner.

PSE identified two additional methods to evaluate presence of individuals while wearing the ExDI suit to complement the survey results of the Independent Assessor. These two methods were recording observations of individuals performing actions in the real world in response to stimuli in the virtual environment (behavioral method) and measuring heart rate (physiological method) during each training scenario.

Observations and the actions the participant makes while in the system may indicate presence. The participant may be unaware they are even doing the action and by recording this information, and linking it to scenario events, a sense of presence may be inferred if the action is similar in response to what an individual may do in the real environment. The second method used to measure presence is the measurement of individual heart rates to determine if they react to potentially stressful events within the virtual environment. If a participant does have a sense of presence in the environment and stressful event occurs, a physiological response should be triggered as if it had occurred in the real world. Bangay and Preston (1998) used a similar technique in their experiment and measured heart rate to determine stress levels. However, their goal was to use a virtual environment to lower the stress level of individuals.

The Expedition Dismounted Infantryman (ExDI) and Virtual Battle Space 2 (VBS2) are recent technologies identified by the FITE JCTD to create a virtual environment which immerses the participant in the combat environment. The goals of this study were to 1) identify whether the FITE immersive environment could provide a level of immersion that could be measured behaviorally and physiologically and 2) Determine if behavior and physiological measures could be used to objectively measure presence – or a sense of being ***in*** the environment rather than the sense of ***watching it***.

EXPEDITION DISMOUNTED INFANTRYMAN (ExDI)

During Spiral 1, the ExDI suit was worn by each of the participants to immerse the participant into the virtual combat environment. The suit is made up of multiple components. It includes a head mounted display of the virtual world providing a 40 degree field of view. The ExDI uses a leg sensor to provide an in-world avatar the ability to mimic the turning and other movements of the participant. The participant can practice and use a replica weapon (M4, M249, M203) of those used on a patrol. The FITE JCTD also attached to each individual a Threat-Fire™ system to provide negative feedback when an individual was shot or near an explosion. The capabilities of the ExDI suit and VBS2 for Spiral 1 were demonstrated during two Operational Demonstrations (ODs) OD-1A was conducted February 23-March 5, 2010 with two squads of

U.S. Marines at Camp Lejeune, NC and OD-1B was conducted March 16-25 2010 with two squads of U.S. Army Soldiers at Fort Benning, GA.

METHOD

Evaluation of level of presence using the Spiral 1 ExDI suit and VBS2 software was collected via observation and physiological data (heart rate) during each scenario to evaluate level of presence experienced by each of the participants. Observation data was collected by PSE researchers during each of the four training scenarios. During each scenario, observers simultaneously watched the physical actions of each participant and observed actions being made in the real world. Observation data collection focused on what actions, movements, etc. the participants made, or tried to make, in response to being in the virtual world. An example of an action showing presence would be if a trainee, communicated to others on his team using hand signals, even though the action could not be seen by his team members in the virtual environment. Startle responses, such as jumping during an explosion, would be another observation indicating the trainee was experiencing presence. Training and other factors that had either a positive or negative effect on squads using the ExDI suit were also noted. Observations were also made to note unique training opportunities presented during the scenarios. Lastly, observations were also recorded whenever conditions were presented that appeared to disrupt or distract the level of presence in the participants.

Physiological measures of the trainee's heart rate during each of the scenarios were recorded. Heart rate is an ideal measure to use during Spiral 1 since the mobility of the individual is somewhat restricted, thus suggesting that any heart rate changes that are detected are probably related to the sense of presence in the environment. To monitor the heart rates of participants, Suunto Dual Comfort Belts® were issued to participants to wear during all scenario runs. Each participant wore a Suunto® heart rate monitoring belt. The heart rate monitoring belt is minimally invasive, requiring the user to only wear a lightweight strap around their chest. Participants were informed that their wearing of the heart rate monitor belt was voluntary. These belts used a Suunto wireless technology called ANT® to transmit the participants' heart rates to the Suunto Team Pod® receiver which is an antenna that connects to a laptop through a USB port. The Suunto Team Pod receiver was connected to a Lenova ThinkPad T60© laptop using the Windows XP© operating system to collect the data in real-time. The Suunto Monitor® version 1.1.2 software and the Suunto Team Manager® version 2.3.0 software were also used during data collection. The Suunto Monitor® software provides real time monitoring of all team members' heart rates and allows the manual time stamping of events when they occur. At the completion of each scenario run, the heart rate data was saved to the Suunto Team Manager® software for further analysis. The data files automatically saved to the Suunto Team Manager® were then exported to Microsoft Excel© to complete the analysis.

From the data obtained using the Suunto ® heart rate monitoring software, average heart rate for each scenario was collected. Further, during each training scenario key events (IED located,

explosion, etc) were timed stamped and served as event markers. The event marks were used to denote key events that occurred during a scenario to identify time locations for evaluated pre/post event heart rate. Increases in heart rate to a kinetic event would be indicative of the individual having a sense of presence. Each participating squad conducted four scenario runs. Scenario 0 and 1 were setup as non-kinetic scenarios while scenarios 2 and 3 involved kinetic attacks near the end of the scenario. All squads went through the scenarios in order except Squad 2 for OD-1B. Squad 2 performed scenario 0 first and then scenario 2 and 3 before running through scenario 1 as their last scenario. Further, Squad 1 for both OD-1A and OD-1B had the opportunity to do a "Free for All" at the end of scenario 3. The "Free for All" was setup as an "everyman for himself" period where each individual participant hunted their fellow squad members to be "King of the Mountain/Last Man Standing."

In addition, the amount of time spent in each of the specific heart rate zones related to Cooper's Color Code (CCC) by the participants was determined. CCC is broken into four conditions that indicate an individual's level of engagement or readiness; white, yellow, orange and red. A fifth condition, often referred to as black, has been adopted by the United Stated Marine Corps but not officially endorsed by Cooper himself. Heart rate zones were later applied for each condition as a composite of CCC and work done by Grossman (Grossman & Christensen, 2004). The heart rate zones are: White: < 80 beats per minute (bpm); Yellow: 81-100 bpm; Orange: 101-120 bpm; Red: 121-140 bpm; Black: >140 bpm. These heart rate zones were entered into the Suunto® software and provided real time monitoring of participant CCC heart rate zone. Figure 1 shows the Suunto® software display of CCC heart rate zone for each participant at a given moment during the scenario.

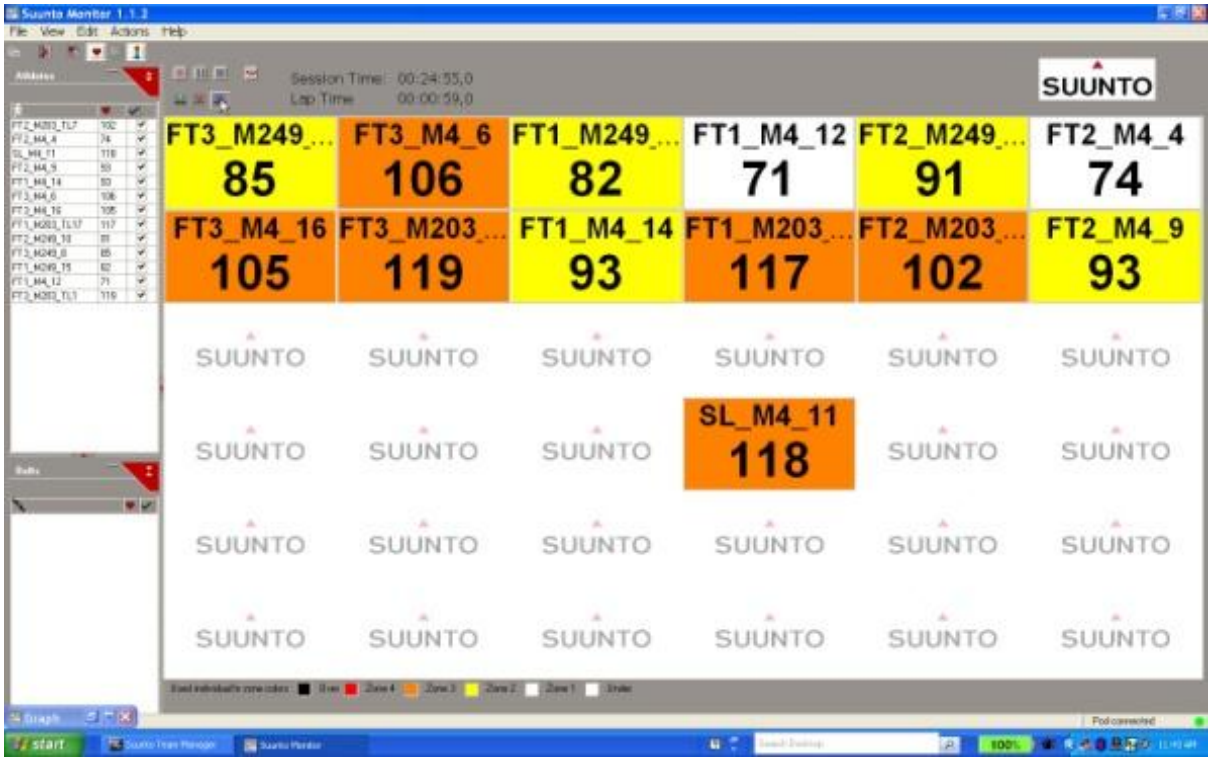

Figure 1. Real-Time Screen Shots from OD-1A During Training Scenarios Associated with Cooper's Color Code.

RESULTS

Behavioral Observations

Behavioral observation were recorded by PSE researchers for both OD-1A and OD-1B to provide examples of positive and negative presence actions while also noting factors that may have interfered with the sense of presence for the participant. Notes were also kept to reflect training and system-related issues that either helped or hindered the participants while using the ExDI suits, and could have had an effect on the sense of presence.

Presence

For OD-1A, a common indicator of positive presence was the observation of participants making actions (behaviors) in the real world to reflect events occurring in the scenario without realizing they were performing these actions. These actions included using hand gestures when speaking, pointing directions (even though no one could see where they were pointing in the virtual world), startle responses, excitement in the participant's voice, and warning others of threats. Pointing directions was a common observation throughout the scenarios but unfortunately was not one that was mimicked in the virtual world, becoming a source of frustration at times for the squad when they realized no one could tell where they were pointing. Participants quickly learned that they could use their weapons as a way pointing. Another action observed demonstrating presence was that a squad's movement and route planning activities changed over time as they gained

more information regarding what to expect in the village. Lastly, one observation was made in which an individual ran out of his real-world training space (almost into a wall) as he was trying to change locations quickly during a fire fight.

There were also several observations made during OD-1A that indicated a lack of presence. This included behaviors such as participants talking to each other or gesturing in the real world to get someone's attention (waving hands, tapping on shoulders, etc.) even if they were separated by a few hundred meters or their view was obscured by a building in the virtual world. Another negative presence aspect was when a participant was "killed" or out of the scenario, they sometimes continued to provide feedback and/or assisted the remaining squad members. During one of the scenarios an external stimulus (vacuuming) may have also affected the sensation of presence of the participants. The vacuuming may have distracted or briefly drawn the attention of participants away from the scenario. An interesting observation that indicated both positive and negative aspects of presence was when the Squad Leader called for the Team Leaders to come to him, there was confusion over whether he meant in the game or in real life or both. This reflects that the participants may have wanted to maintain a sense of presence but at the same time realized the existence of the real world in which they were also interacting.

For OD-1B similar observations were made for the sensation of presence. Again, participants used hand gestures in the real world to point out direction, location, etc. There was also an instance where a Squad Leader reported feeling "nervous" while they was near an Improvised Explosive Device (IED) site, even though it was not a really a physical threat, except for the possibility of getting shocked by the Threat-Fire™ system if the IED went off. There was also an incident between a Squad Leader and his Team Leader in which the Squad Leader told the Team Leader "I can't talk to you - you're too far away. We have to use radios." This simple exchange is again reflective of how the Squad Leader attempted to maintain a sense of presence in the scenario, even though he was standing close to the Team Leader, to hold a conversation. Another interesting reaction occurred during the "Free for All" event when an aircraft flew overhead and the soldiers reacted by ducking as if they had to hide or find cover.

There were also several observations made during OD-1B that indicated a lack of presence. For example, the Squad Leader often needed to look at a real-world hard-copy map of the village which meant that he had to raise his visor to look at the map, likely breaking the sensation of presence in the virtual world. During the scenarios there were also some technical issues (e.g., freezing of the system) that affected only a few of the participants, but served as a distraction if the scenario needed to be paused. Unfortunately, sometimes the affected participant would speak loudly to voice their issue and frustration, which may have affected the sensation of presence for other participants still operating in the virtual world.

A general observation for both demonstrations that affected the sensation of presence was the ambient lighting in the demonstration rooms. To help reduce some of the external visual distractions with movement seen in their periphery, the ambient lighting needs to be set to a low

level. In both ODs, the lights were dimmed slightly after the scenario began but due to other issues such as needing lighting during video capture the lights were often turned back up.

Game-Related Considerations

During OD-1A, it was observed that individuals at the beginning were moving alone in the system and other squad members were having a hard time tracking them, indicating that more training needed to be done on squad movement in the virtual world. Participants further noted it was hard for them to judge distance, though later, during one of the scenarios, one of the Marines reported the estimated distance of the origin of fire and was fairly accurate in his estimation. A training opportunity that did occur during OD-1A was when the participants entered a house with female characters; they were then provided a learning opportunity for cultural decision making and how to deal with females from another culture. Lastly, one interesting observation that was made during preparation phase, when participants were going through the obstacle course to learn the system, was when one of the Marines fell off the roof and was injured the corpsman quickly ran over to the man and dragged him to cover (in the virtual world).

Some difficulties with individual movement were noted in OD-1B, which contributed to squad movement during the baseline scenario being not tactically sound. This again reflects that more training may be needed to learn how to move better in the system. In fact, Squad 2 ended up getting lost during the baseline scenario and had to pause for a map recon. This indicates that the squad may have needed more time learning to move and navigate in the virtual environment.

Heart Rate Results

Initial analysis was conducted to investigate heart rate changes between a baseline period (averaged heart rate over the period two minutes before and after the scenario start time) and an end phase (average heart rate over the last 15 minutes of each scenario). Figures 2 and 3 display the average heart rate differences between these time periods for each of the scenarios during OD-1A and OD-1B respectively. While these results do show that the participants were engaged, they do not necessarily reflect a sense of presence since they are not associated with specific behavior.

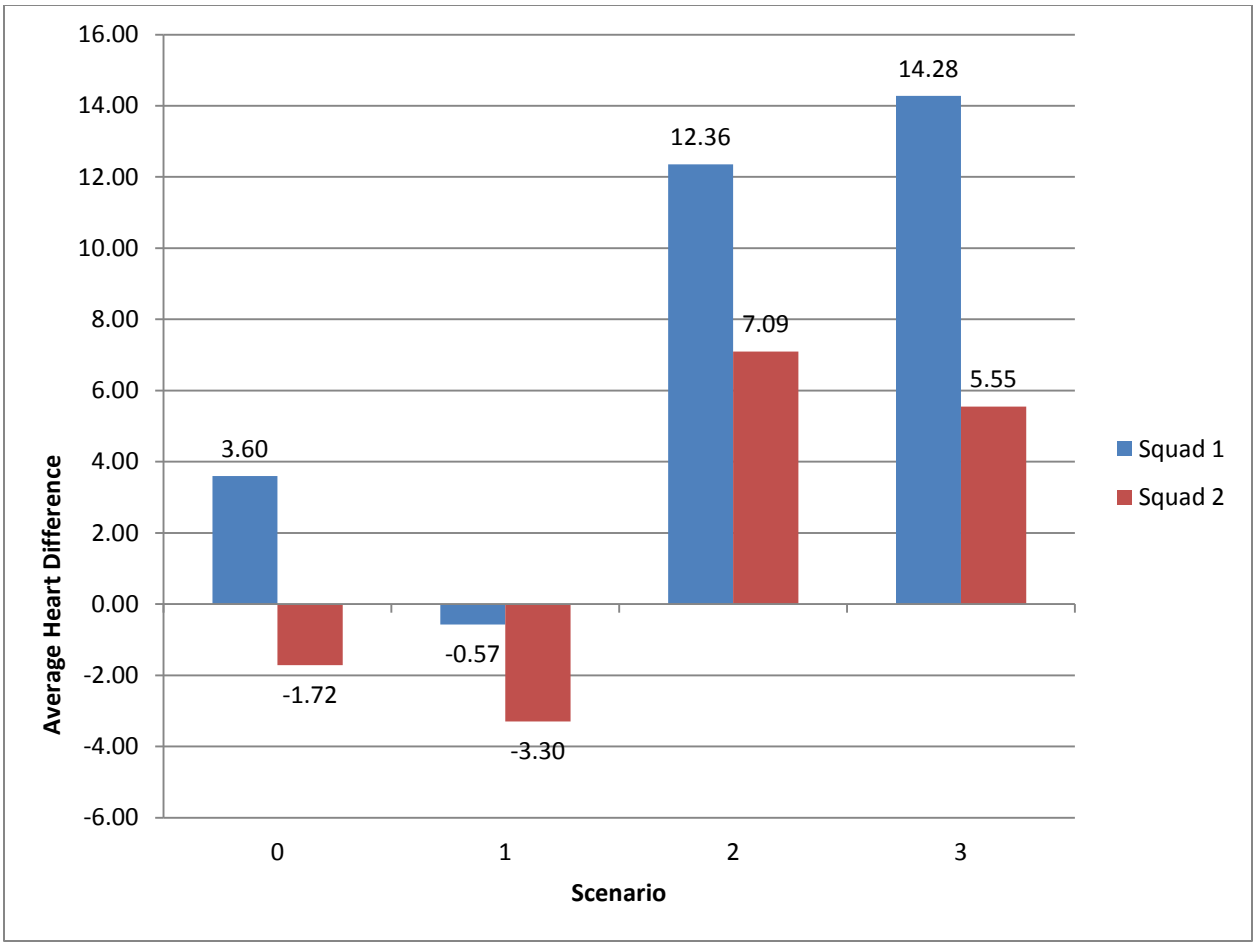

Figure 2. Average difference in heart rate between baseline and end of scenarios for OD-1A.

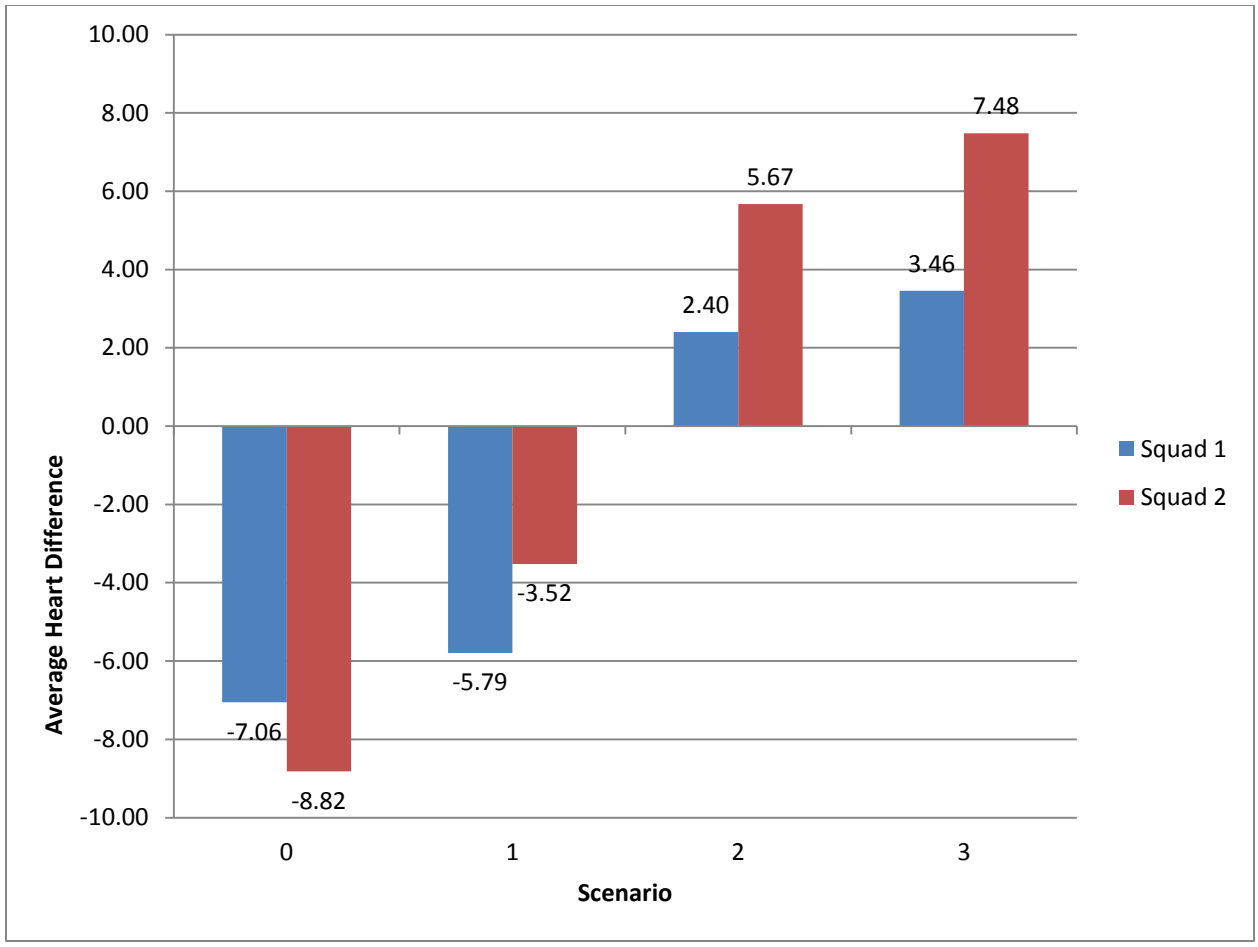

Figure 3. Average difference in Heart Rate between Baseline and End of Scenarios for OD-1B.

To evaluate presence, specific scenario events were identified and pre-to-post (PTP) heart rate measures were collected for analysis. Average heart rate values were determined for the three minute period prior (Pre) to each event and over a three minute period after (Post) each event. Statistical analyses (paired *t*-test) were conducted independently for each event. To select the events for analysis, time markers for each event were identified on the heart rate data displays for all participants. Visual reviews of changes in heart rate were then observed for each of the events. Only events that displayed large increases in heart rate as a group were selected for statistical analysis. This technique helped reduce the number of analyses that needed to be conducted while maximizing the opportunity of demonstrating presence.

Event-based Heart Rate for OD-1A

For OD-1A, eight events were selected for analyses for PTP heart rate differences. The only events with a common theme between the two squads were the "Initial Attack" event that occurred in scenarios 2 and 3 and the "RPG Attack/Identification" that occurred in scenario 3. All other events were unique to a squad within a given scenario. Table 1 shows which analyses were conducted and the statistical results. Analyses were only conducted in cells containing symbols.

No visually apparent heart rate changes related to specific events were found during scenario 1. Therefore, no analyses were conducted for this scenario. In addition, Squad 2 did not display visually apparent increases in heart rate related to any events in scenario 0. Table 1 displays the statistical results of PTP heart rate analyses during OD-1A.

Table 1. OD-1A statistical results for *t*-tests pre/post significant scenario events.

Event	Contact	Initial Attack	Shots-small arms	Engage	RPG Attack /Identification	Taking fire	RPG gunner to the north	Free for All
Squad 1								
Scenario 0	**							
1								
2		**	*	**				
3		***			**			***
Squad 2								
Scenario 0								
1								
2		**						
3		***			**	***	***	

*** (p<0.1); ** (p<.05); *** (p<.01)**

Statistically significant increases in PTP heart rate were found for all analyses conducted for the OD-1A participants. Table 2 shows the percentage of squad members that demonstrated an increase in heart rate. At least 75% of all participants whose data were recorded for the scenarios showed an increase in heart rate for events identified. Further, all of the participants displayed an increase in heart rate for two events, "RPG gunner to the north" for Squad 1 and "Free for All" for Squad 2. Table 2 reflects the percentage of Marines that demonstrated an increase in heart rate related to each of the specific events. These results indicate that the statistical results are driven by group data rather than an individual outlier.

Table 2. Percentage of Participants in OD-1A that Showed an Increase in Heart Rate.

Event	Contact	Initial Attack	Shots-small arms	Engage	RPG Attack /Identification	Taking fire	RPG gunner to the north	Free for All
Squad 1								
Scenario 0 (N=12)	83%							
1 (N=11)								
2 (N=10)		80%	80%	80%				
3 (N=12)		92%			75%			100%
Squad 2								
Scenario 0 (N=13)								
1 (N=12)								
2 (N=13)		69%						
3 (N=12)		92%			83%	92%	100%	

To illustrate how the heart rates varied due to specific events during OD-1A, representative data are displayed in Figures 4 and 5 for Squad Leader 1 for scenario 2 (Figure 4) and for all

participants from Fire Team 2 for scenario 2 (Figure 5). Each participant's heart rate over the course of the scenario is identified by a different colored line as noted in the figure legend. At the top of the figure are three events that were identified for that scenario, and the period of time when the event occurred. One of the three individuals showed a very large increase in heart rate for the events, and the Squad as a whole also exhibited significant increases in PTP heart rate for each of the events. Figure 5 shows how individuals responded differently to each of the events. Yet, during each of these events, 80% of the squad did display an increase in heart rate.

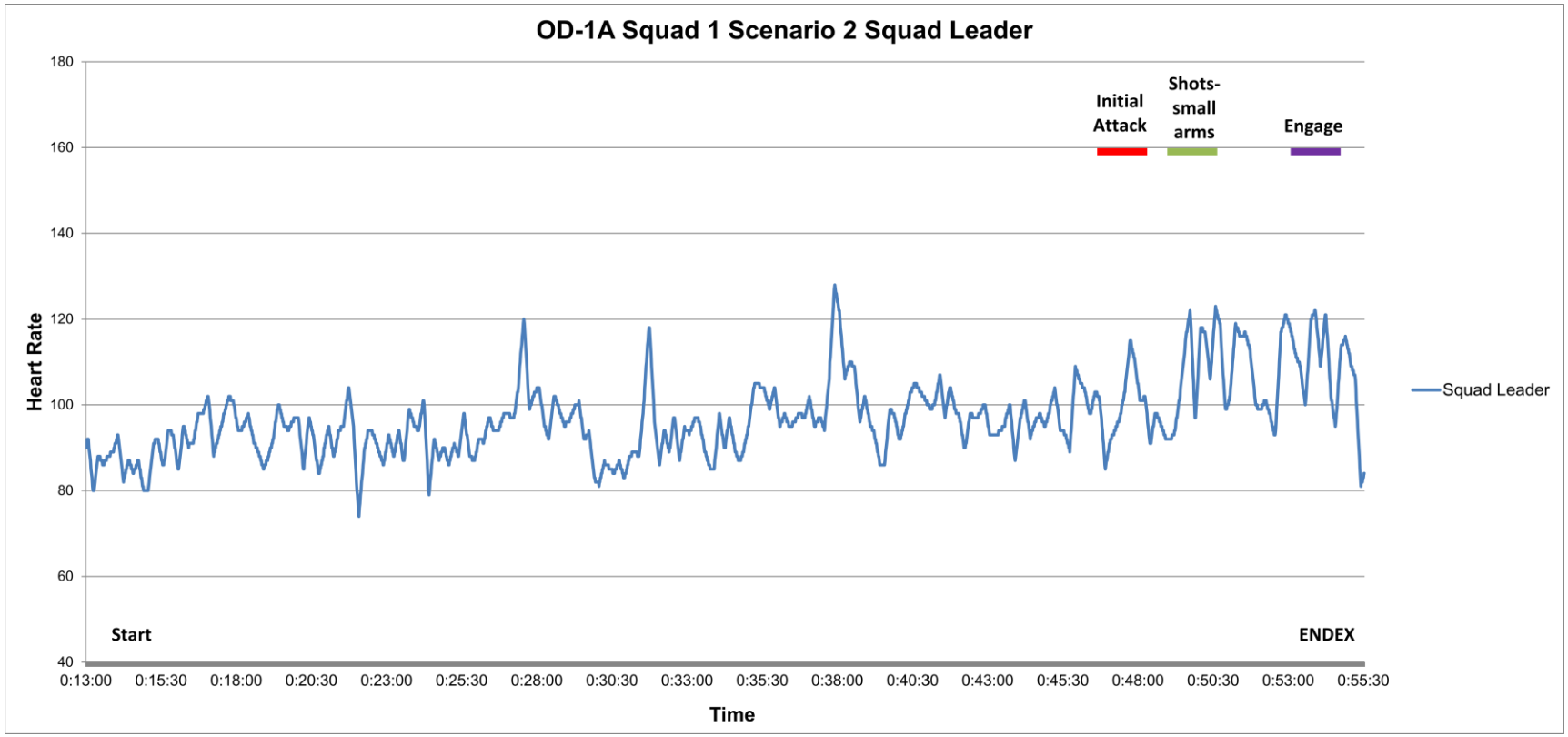

Figure 4. Heart rate data recorded during OD-1A for Squad Leader for Scenario 2.

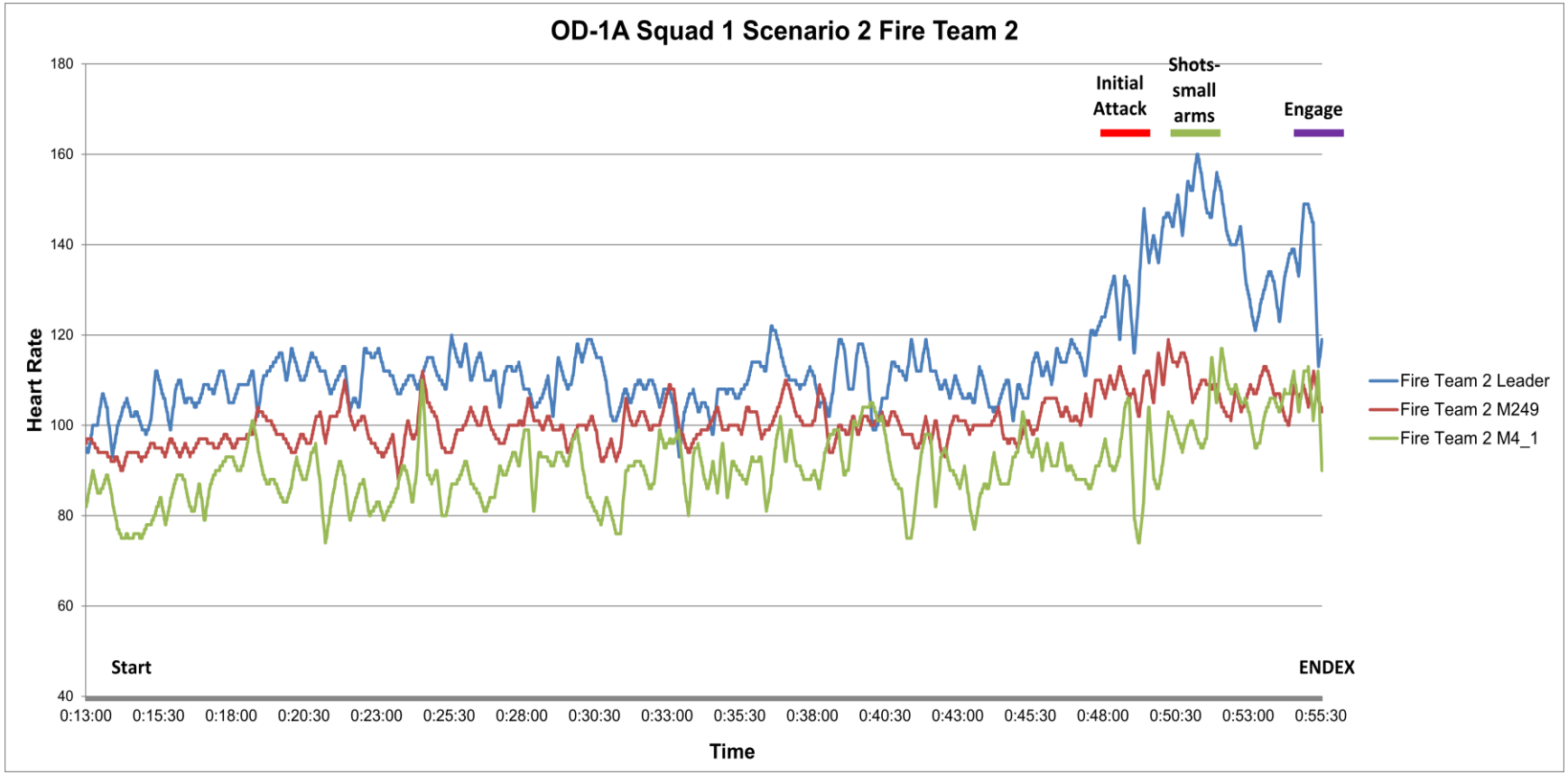

Figure 5. Heart rate data recorded during OD-1A for Fire Team 2 for Scenario 2.

Cooper's Color Code OD-1A

In addition, heart rate data was tracked to provide an estimation of how much time during a scenario an individual's heart rate was within each condition of Cooper's Color Code (CCC). As a unit, both squads averaged heart rates in the yellow condition across all scenarios. However, as shown earlier, there were individual differences. For example, Marines in Squad 1 had seven men with average heart rates that placed them in condition yellow, five men in condition orange, and one individual who was in condition white. Squad 2 had six Marines in condition yellow, five in orange and one in white. The distribution across both squads was very similar. Representative data from this type of analysis is displayed in Table 3 for one of the squads for each scenario during OD-1A.

Table 3 shows percentage of time participants spent in each condition of CCC during each scenario. The condition participants spent the most time in is highlighted for each scenario. Scenario 0 was Squad 1's first scenario wearing the ExDI suit and most of the squad was in either condition orange or yellow, suggesting that they were engaged or excited to be in the event, probably anticipating kinetic activity. Scenario 1 consisted of a non-kinetic patrol and most of the participants spent the majority of their time in the yellow condition. Scenario 2 was the first fully kinetic scenario and the majority of participants showed a heart rate increase and spent most of their time in condition orange. Scenario 3 was also a kinetic scenario but now the majority of participants spent most of their time in condition yellow. Such a result may be reflective of a reduction in general stress level (or uncertainty) due to having already experienced kinetic events within the system.

One interesting note is that the Squad Leader always spent a majority of his time in condition yellow regardless of the scenario.

Table 3. OD-1A: Squad 1 - Percentage of time in CCC conditions

Scenario 0	FTL1	FT1-1	FT1-2	FT1-3	FTL2	FT2-1	FT2-2	FT2-3	FTL3	FT3-1	FT3-2	FT3-3	SL
Black	--	--	--	--	--	--	--	--	--	--	--	--	--
Red	1%	5%	--	--	14%	--	--	--	--	10%	--	6%	--
Orange	**82%**	**57%**	9%	1%	**77%**	27%	4%	7%	--	**90%**	**53%**	**90%**	11%
Yellow	17%	38%	**88%**	46%	8%	**73%**	**57%**	**62%**	--	--	43%	4%	**87%**
White	--	1%	4%	**53%**	--	--	39%	31%	--	--	4%	--	2%
Avg. HR	105	103	92	80	111	97	83	86	--	116	99	110	92

Scenario 1	FTL1	FT1-1	FT1-2	FT1-3	FTL2	FT2-1	FT2-2	FT2-3	FTL3	FT3-1	FT3-2	FT3-3	SL
Black	--	--	--	--	--	--	--	--	--	2%	--	--	--
Red	--	--	--	--	--	--	--	--	--	3%	--	--	--
Orange	6%	28%	**60%**	--	10%	11%	--	--	--	**75%**	24%	**69%**	5%
Yellow	**88%**	**72%**	30%	--	**80%**	**87%**	21%	15%	--	9%	**75%**	31%	**67%**
White	5%	--	9%	--	10%	2%	**79%**	**85%**	--	11%	2%	--	27%
Avg. HR	91	95	96	--	91	93	75	76	--	106	96	102	84

Scenario 2	FTL1	FT1-1	FT1-2	FT1-3	FTL2	FT2-1	FT2-2	FT2-3	FTL3	FT3-1	FT3-2	FT3-3	SL
Black	--	6%	--	--	5%	--	--	--	--	--	--	2%	--
Red	--	8%	33%	--	28%	--	--	--	--	15%	3%	32%	1%
Orange	**55%**	24%	**46%**	--	**56%**	**52%**	9%	--	--	**85%**	**66%**	**59%**	36%
Yellow	45%	**52%**	19%	--	11%	48%	**80%**	--	--	--	31%	8%	**62%**
White	--	9%	2%	--	--	--	12%	--	--	--	--	--	1%
Avg. HR	103	101	112	--	116	100	90	--	--	114	103	116	98

Scenario 3	FTL1	FT1-1	FT1-2	FT1-3	FTL2	FT2-1	FT2-2	FT2-3	FTL3	FT3-1	FT3-2	FT3-3	SL
Black	1%	17%	--	--	2%	--	--	--	--	--	--	11%	--
Red	5%	9%	17%	--	8%	--	5%	--	--	26%	14%	17%	5%
Orange	22%	16%	**57%**	--	29%	--	15%	--	--	**63%**	25%	**42%**	20%
Yellow	**68%**	**49%**	24%	20%	**57%**	**57%**	**51%**	22%	--	11%	**59%**	31%	**69%**
White	3%	8%	1%	**80%**	5%	43%	29%	**79%**	--	--	2%	--	6%
Avg. HR	96	106	108	74	99	82	89	77	--	113	100	112	94

Heart Rate for OD-1B

Eight scenario events were also identified for OD-1B. PTP heart rate analyses were conducted for each of these events and statistical results are displayed in Table 4. As in OD-1A, no specific events were identified during scenario 1. There were unique events between squads and across scenarios such as Squad 1's "Hand's up, don't move" event during scenario 0.

Table 4. OD-1B statistical results for *t*-tests pre/post significant scenario events.

Event	"Hand's up, don't move"	Initial Attack	Suspected Attacker spotted	Man/Men down	Meet with local	Unknown shots fired	"Truck!"	Free for All
Squad 1								
Scenario 0	***							
1								
2		NS	***	***				
3		**		*	**			***
Squad 2								
Scenario 0								
1								
2		***	***	***				
3		*		**		*	***	

*** (p<0.1); ** (p<.05); *** (p<.01): NS (Not Significant)**

Again not all the participants showed an increase in heart rate during each key event. Table 5 shows that at least 56% of participants displayed increases in heart rate for the scenario events identified. For eight of the events all members of the squad displayed increases in heart rate for the specific event.

Table 5. Percentage of Participants in OD-1B that Showed an Increase in Heart Rate.

Event	"Hand's up, don't move"	Initial Attack	Suspected Attacker spotted	Man/Men down	Meet with local	Unknown shots fired	"Truck!"	Free for All
Squad 1								
Scenario 0 (N=9)	100%							
1 (N=9)								
2 (N=8)		63%	88%	100%				
3 (N=9)		89%		56%	78%			100%
Squad 2								
Scenario 0 (N=9)								
1 (N=8)								
2 (N=8)		100%	100%	100%				
3 (N=9)		78%		100%		78%	100%	

To illustrate how the heart rates varied due to specific events during OD-1B, representative data are displayed for Squad Leader 1 for scenario 2 (Figure 6) and for all participants from Fire Team 2 for Scenario 2 (Figure 7). When the "Initial Attack" occurred all participants' heart rates showed an increase, and then decreased soon after the event was over. This was soon followed by the event "Suspected Attacker Spotted" which caused all participants' heart rates to increase. When "Suspected Attacker Spotted" occurred it was immediately followed by "Man/Men down." This event involved four of the squad members being "shot/out" of the scenario, including the Squad Leader. In Figure 6, the Squad Leader's heart rate is shown spiking as he is shot, and rapidly decreasing as soon as he was eliminated from the scenario. Fire Team 1 Leader was also one of the "men down", meaning that it was the task of Fire Team 1 M4_1 to take over as team leader. Figure 7 shows the rapid increase in his heart rate as he takes over command.

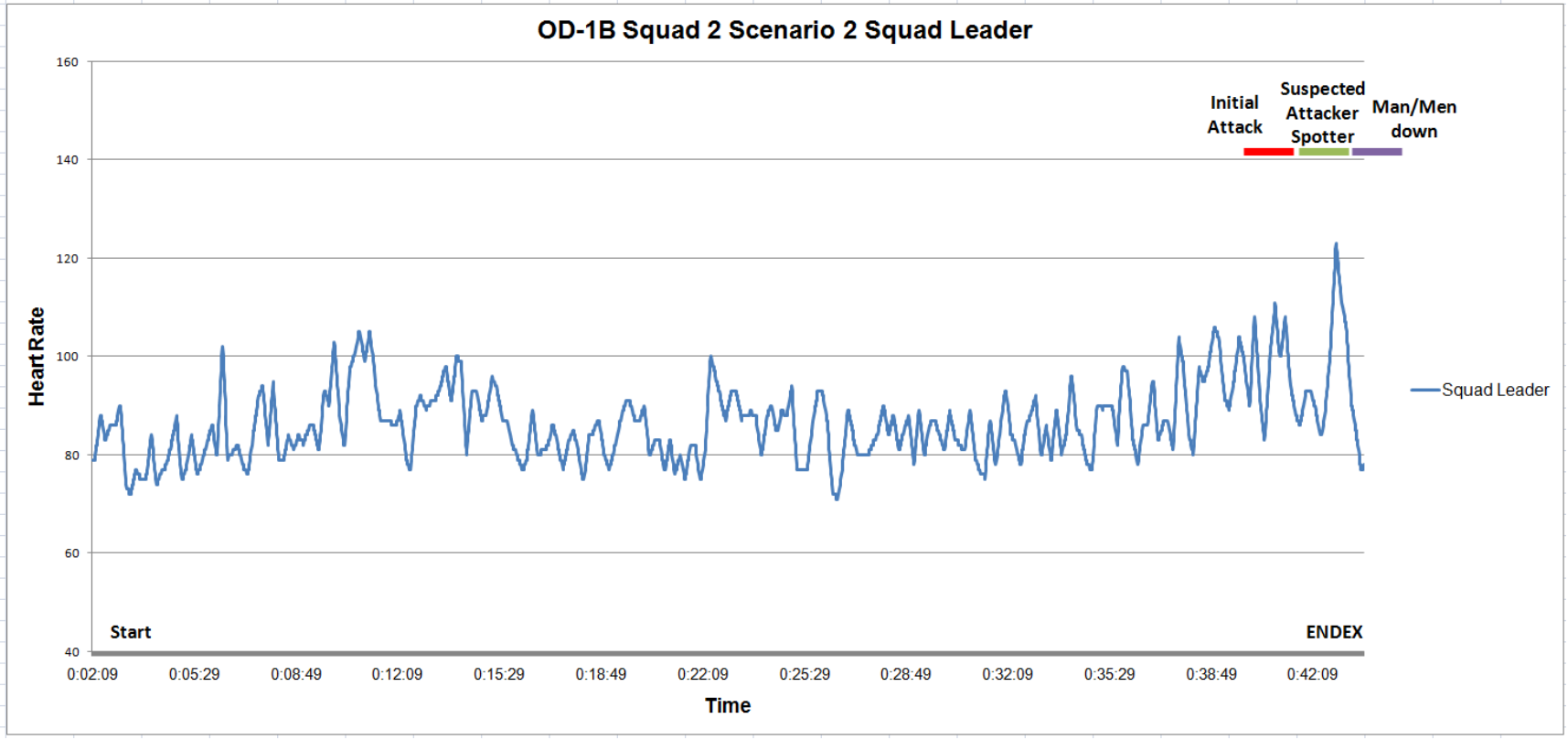

Figure 6. Heart rate data recorded during OD-1B for Squad Leader for Scenario 2.

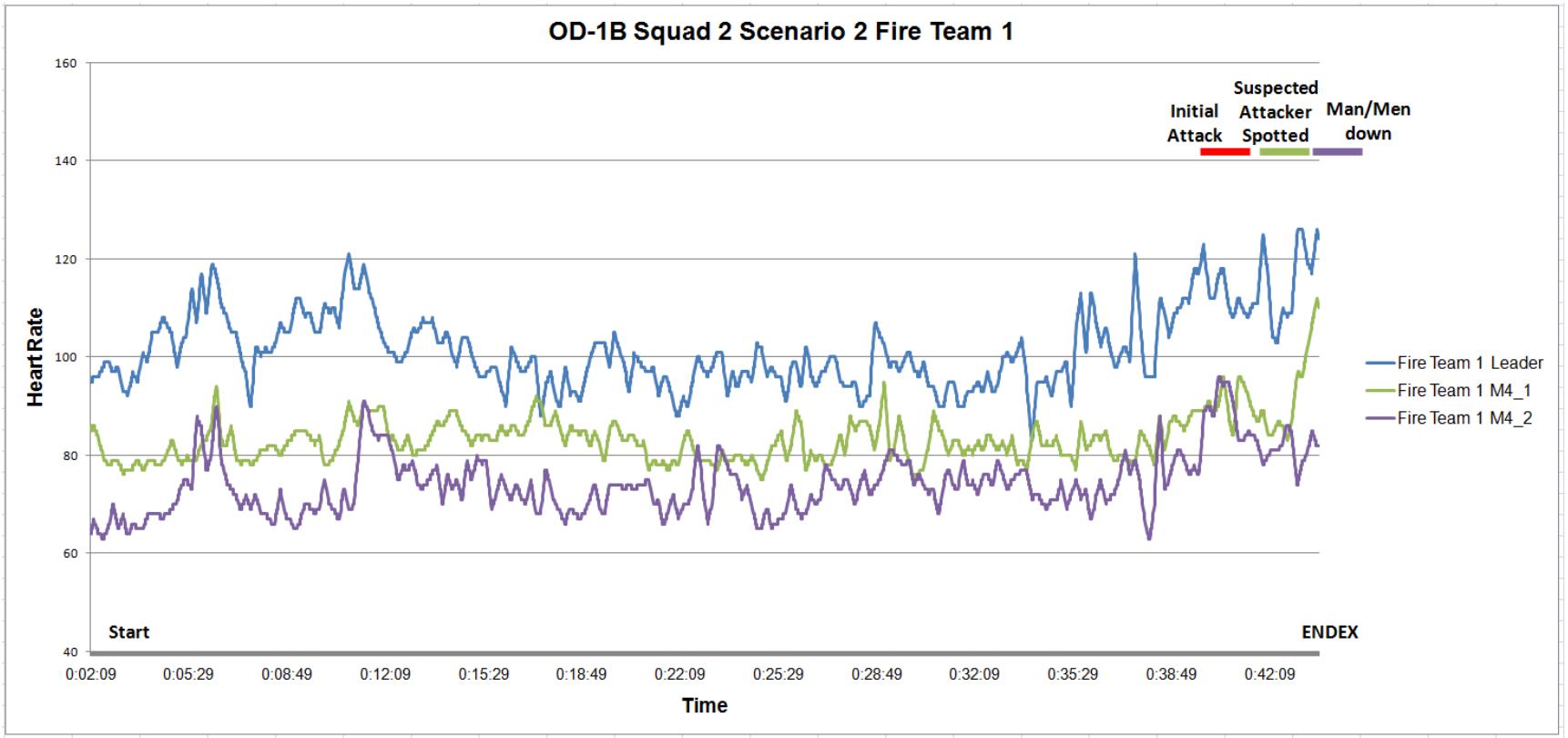

Figure 7. Heart rate data recorded during OD-1B for Fire Team 1 for scenario 2.

Cooper's Color Code OD-1B

Heart rate data are tracked to provide an estimate of how much time during each scenario an individual spent within each condition of CCC during OD-1B. As a whole, the two squads averaged heart rate in the condition yellow for all scenarios. The distribution for the individuals in both squads had six men with average heart rates that placed them in condition yellow, two men in condition orange, and one individual who was in condition white.

Table 6 shows the percentage of time participants from Squad 2 spent in each condition of CCC during a scenario, with the condition the participant spent the most time in for that scenario highlighted. For scenario 0, participants tended to remain in either condition yellow or white with minimal time spent in the other conditions. The data for Scenario 1 show that the majority of participants had heart rates that placed them in condition yellow or white, with two individuals spending a majority of their time in orange or red. Although scenario 2 was a kinetic scenario, only two members of the squad spent the majority of their time in orange while the rest where in yellow or white. Scenario 3 had three members spend a majority of their time in conditions red or orange while the rest of the squad remained in condition yellow or white. For all the scenarios, no member of Squad 2 was ever in condition black.

Of note, the Squad Leader displayed heart rate data indicating that he spent most of his time in condition yellow for the non-kinetic scenarios (scenarios 0 and 1) but was in condition orange for the kinetic scenarios (scenarios 2 and 3).

Table 6. OD-1B: Squad 2 - Percentage of time in CCC conditions

Scenario 0	FT1TL	FT1-1	FT1-2	FT1-3	FT2TL	FT2-1	FT2-2	FT2-3	SL
Black	--	--	--	--	--	--	--	--	--
Red	--	--	--	--	--	--	--	--	--
Orange	28%	1%	14%	--	4%	14%	--	4%	18%
Yellow	**72%**	**74%**	**86%**	6%	**84%**	**78%**	5%	**93%**	**82%**
White	--	25%	--	**94%**	12%	8%	**95%**	3%	--
Avg HR	97	85	94	72	86	91	72	90	95

Scenario 1	FT1TL	FT1-1	FT1-2	FT1-3	FT2TL	FT2-1	FT2-2	FT2-3	SL
Black	--	--	--	--	--	--	--	--	--
Red	2%	--	--	--	3%	**33%**	--	1%	--
Orange	**58%**	5%	3%	--	7%	28%	--	31%	26%
Yellow	39%	**90%**	**76%**	34%	38%	28%	30%	32%	**59%**
White	--	6%	21%	**66%**	**52%**	11%	**70%**	**37%**	15%
Avg HR	105	89	87	76	83	108	77	91	90

Scenario 2	FT1TL	FT1-1	FT1-2	FT1-3	FT2TL	FT2-1	FT2-2	FT2-3	SL
Black	--	--	--	--	--	--	--	--	--
Red	5%	1%	1%	--	5%	--	--	--	2%
Orange	**73%**	13%	42%	--	37%	4%	--	7%	**68%**
Yellow	22%	**73%**	**57%**	6%	**57%**	**59%**	33%	**77%**	30%
White	--	12%	--	**93%**	1%	37%	**67%**	16%	--
Avg HR	106	91	100	72	99	84	78	88	103

Scenario 3	FT1TL	FT1-1	FT1-2	FT1-3	FT2TL	FT2-1	FT2-2	FT2-3	SL
Black	--	--	--	--	--	--	--	--	--
Red	**51%**	--	--	--	1%	--	--	--	13%
Orange	48%	11%	4%	--	42%	15%	--	**65%**	**81%**
Yellow	1%	**78%**	**95%**	25%	**56%**	**77%**	48%	34%	6%
White	--	10%	1%	**74%**	--	7%	**52%**	--	--
Avg HR	120	90	90	76	100	91	80	102	111

DISCUSSION

While it is impossible to completely simulate a real-world patrol situation that includes the risk of gunfire, explosions, and injuries and death, the FITE JCTD was designed to create an immersive virtual environment that closely represents what a Marine or Soldier could encounter while on patrol. The question of how close to reality the virtual environment is to combat conditions and situations infantryman face in theater can be addressed by using different methods tied to measuring the sensation of presence. These methods include subjective (surveys), behavioral (observations) and physiological (changes in heart rate). The results displayed here clearly demonstrate that the ExDI /VBS2 Spiral 1 system did provide sufficient immersion to produce the sensation of presence.

Behavioral observation results revealed that participants clearly performed specific actions and behaviors that might have been expected if they were in actual real-world environment. These actions included making hand movements while talking, or indicating direction by pointing to other squad members. Further, this training provided many additional unique opportunities for training in situations to which few infantrymen are exposed before experiencing them in theater. One example that arose in one of the scenarios was what actions to take while under attack in a school with children present. Multiple learning/training opportunities arose during the AARs where the participants could view their behavior via replay and learn from their actions. The participants used these talking points to discuss how to make better decisions in future scenarios and in real-world situations.

Heart rate increases were found across scenarios for all squads. However, to more specifically evaluate presence, event-based heart rate results were analyzed. These results show that a when an event occurred in the virtual world that would normally be expected to produce an increase in heart rate in the real world, the heart rates of the participants did increase. There were individual differences, but the majority of the squad members showed similar results. A compelling investigation for future work would be analysis of how HR changes may reflect a participant's proximity to the event, their level of situation awareness, their experience level, or a host of other factors.

Survey data were collected by the Independent Assessor to provide subjective reports of the participants' sense of presence in the scenarios. Overall, although the correlations between survey data and heart rate data were not statistically significant, participants did show that they were exhibiting a sensation of presence for events within a scenario based on observed actions and heart rate. The lack of correlation is probably related to the fact that all participants indicated a moderate level of presence based upon the questionnaire data. One key to this data is that heart rate measures must be linked to event-based activities that occur within a scenario. The linking of events to changes in observed actions and heart rate served as a method to show that presence did occur. Subjective reports may have been based primarily on overall experiences, rather than tied to specific scenario events. One needs to be aware that subjective reports do not always match objective data.

An example of this occurred during the FITE JCTD Technical Demonstration. During a scenario, the Squad Leader was killed and removed from the scenario. One of the Fire Team Leaders, Davis (not his real name), was forced to take over as Squad Leader around the 20 minute mark (blue square marker on graph in Figure 8). Soon after Davis took over as Squad Leader a rapid increase in his heart rate was recorded, exceeding 174 bpm by the end of the scenario run (reflected by the green line). When asked afterwards what he thought when it became clear that he needed to take over as Squad Leader, he stated that "it was nothing" indicating that he experienced no stress when moved into a position of higher responsibility. His physiological data, in contrast, indicate that his body (and mind) thought otherwise. The data in Figure 8 shows that sometimes there is a disconnection between what someone experiences and what they report.

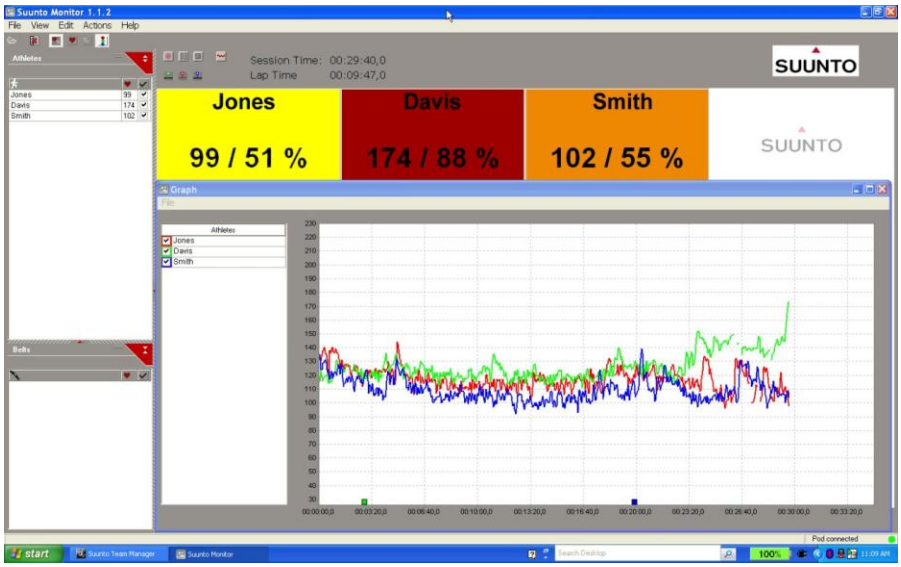

Figure 8. Real-time graph of Technical Demonstration 1 Team Leader's heart rate

The results from the Cooper's Color Code data also demonstrate that a sense of presence was apparent across the scenarios. Although there are individual differences, for the most part, the participants' heart rates placed them in a CCC condition appropriate for the scenario event. In other words, when patrolling and observing they were in the yellow, and when faced with threats or engaged in combat they spent more time in orange or higher. These data demonstrate modulation of physiological responses in the virtual world that are similar to what would be expected in the real world.

Potential Caveats

The demonstration overall was not a controlled experiment and confounding variables may have influenced the results. Participants were not monitored for variables like caffeine and nicotine use, athletic ability, and naturally high or low heart rates. These could all have an effect on participants' starting heart rate or baseline, which could affect results. For future studies, more control should be employed.

Conclusion

The FITE JCTD was designed to show that a system can be created in which an infantryman can receive immersive, realistic small unit training with minimal risk of harm. One important aspect to this effort was to demonstrate that the technology produced a sensation of presence within participants. In this limited demonstration, PSE showed that by using observational data and recording of participants' heart rates during scenarios, participants did experience a sensation of presence. The key to these findings is the use of event-based activity as the independent variable, analyzing heart rate changes prior to and immediately following a specific event. While

confounding variables may have been present, these data suggest that the FITE system holds promise as an immersive training tool.

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